Lingcod (*Ophiodon elongatus*) Egg Mass and Reef Fish Density SCUBA Survey in the Strait of Georgia, February 13 – 27, 2007

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LINGCOD (*Ophiodon elongatus*) EGG MASS AND REEF FISH DENSITY SCUBA SURVEY IN THE STRAIT OF GEORGIA, FEBRUARY 13 – 27, 2007

by

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TABLE OF CONTENTS

Table Of Contents iii
List of Tables iv
List of Figures v
List of Appendix Tables vi
Abstract vii
Résumé viii
Introduction 1
Methods 1
  Quadrat Dives 2
    Lingcod Egg Masses 2
    Reef Fishes 3
    Habitat and substrate characteristics 3
  Observational Dives 3
  Analysis 3
Results 4
  Egg Mass Density 4
  Egg Mass and Guarding Male Observations 5
    Egg Mass Location and Appearance 5
    Egg Mass Volume 5
    Guarding Males 5
    Egg Mass Volume as a Function of Guarding Male Length 6
  Reef fish density 6
    Lingcod 6
    Other Reef Fishes 6
  Site affinity 7
Discussion 7
Acknowledgements 7
Literature Cited 8

LIST OF TABLES

Table 1. Position and depth of anchor buoy, visibility, number of guarded and un-guarded lingcod egg masses, and egg mass density (egg masses / m^2) , for quadrat dives and observational dives at Snake Island Reef, February 13 – 27, 2007. 10

Table 2. Complexity of habitat, relief (slope), substrate type, and coverage by *Agarum sp.* for lingcod egg mass quadrat dives at Snake Island Reef, February 13 – 27, 2007. Quadrats indicated with bold type contained egg masses. 11

Table 3. Characteristics of each egg mass and guarding male observed during quadrat dives at Snake Island Reef, February 13 – 27, 2007. Egg masses are numbered consecutively in the order in which they were discovered. "N/A" indicates "not available" and refers to egg masses that were located too far under a rock to measure, or males that swam away before they could be measured. 12

Table 4. Reef fish observations from quadrat dives at Snake Island Reef, February 13 – 27, 2007. Total counts and densities (fish / m^2) in each quadrat are provided for lingcod (*Ophiodon elongatus*), copper rockfish (*Sebastes caurinus*), quillback rockfish (*S. maliger*) and kelp greenling (*Hexagrammos decagrammus*). For lingcod, the number of guarding males included in the total is indicated in brackets. For copper and quillback rockfish, the number of juveniles included in the total is indicated in brackets. For kelp greenling, the number of males (m) and/or females (f) included in the total is indicated in brackets. Total counts in each quadrat are provided for tiger rockfish *(S. nigrocinctus*), striped seaperch (*Embiotoca lateralis*) and wolf-eel (*Anarrhichthys ocellatus*). 13

Table 5. Characteristics of egg masses and guarding males observed during observational dives at the Genetics site at Snake Island Reef, February 27, 2007, and February 20, 2004 (JRK: Unpublished Data). Egg masses are numbered according to the numbered locations established in 2002 and 2003 (King and Wither 2005). "N/A" indicates "not available" and refers to males that swam away before they could be measured. "--" indicates no measurements were recorded. 14

LIST OF FIGURES

Figure 1. Location and bathymetry of Snake Island Reef in the Strait of Georgia near Nanaimo, British Columbia, study site for lingcod egg mass and reef fish density surveys in 1990, 1991, 1994 and 2001 – 2007. 15

Figure 2. A) Box plots of lingcod egg mass densities at Snake Island Reef in 1990, 1991, 1994, and 2001 – 2007; and B) box plots of lingcod egg mass volumes at Snake Island Reef in 2002 – 2007. The heavy horizontal line inside each box represents the median, while box edges depict the 1st and 3rd quartiles. The range of the data are represented by the whiskers. The mean density is represented by •, while outliers are represented by ○. 16

Figure 3. A) Box plots of guarding lingcod densities at Snake Island Reef in 1990 and 2001 – 2007; and B) egg mass volume as a function of guarding male length for 2002 – 2007. For box plots, the heavy horizontal line inside each box represents the median, while box edges depict the 1st and 3rd quartiles; the range of the data are represented by the whiskers; the mean density is represented by •, while outliers are represented by ○. 17

Figure 4. Box plots of reef fish densities at Snake Island Reef for lingcod in 2001 – 2007 and copper rockfish, quillback rockfish, and kelp greenling in 2004 – 2007 . The heavy horizontal line inside each box represents the median, while box edges depict the 1st and 3rd quartiles. The range of the data are represented by the whiskers. The mean density is represented by •, while outliers are represented by ○. 18

LIST OF APPENDIX TABLES

Appendix Table 1. Summary of lingcod egg mass density and volume, lengths of guarding males, and density of reef fishes at Snake Island Reef in 1990, 1991 and 1994 (Yamanaka and Richards 1995, K.L. Yamanaka, Unpublished Data, Pacific Biological Station, Nanaimo, BC V9T 6N7), 2001 (King and Beaith 2001), 2002 (King and Winchell 2002), 2003 (JRK: Unpublished Data), 2004 (King and Haggarty 2004), 2005 (Haggarty *et al.* 2005), 2006 (Haggarty and King 2007), and 2007. 19

ABSTRACT

Surry, A.M. and King, J.R. 2007. Lingcod (*Ophiodon elongatus*) egg mass and reef fish density SCUBA survey in the Strait of Georgia, February 13 – 27, 2007. Can. Tech. Rep. Fish. Aquat. Sci: 2743: viii + 19 p.

Dives were conducted at Snake Island Reef in the Strait of Georgia, British Columbia, from February 13 – 27, 2007 in order to estimate lingcod (*Ophiodon elongatus*) egg mass density on the reef, as well as to make observations of the characteristics and locations of egg masses, and to provide density estimates for lingcod, rockfish (*Sebastes spp.*), and other reef fishes present on the reef. Snake Island Reef is an index site that has previously been surveyed in 1990, 1991, 1994, and annually from 2001 – 2006. Egg mass density data were collected each survey year; however, quantitative data on egg mass volume were only collected in 2002 – 2007. Guarding male length and total lingcod density data were collected in 1990 and annually in 2001 – 2007. Reef fish density data were collected each year in 2004 – 2007. Nest site affinity was examined in 2002 – 2003, 2004, and 2007.

Eight egg masses were observed within a total surveyed area of 330 m^2. Egg mass density over the surveyed area ranged from 0 – 0.0064/m^2 per quadrat, with a median of 0/m^2 and a mean of 0.0016/m^2. Egg mass density was lower in 2007 than in 1994, 2002, and 2003, but was not significantly different than in 2004 – 2006. Egg mass volume ranged from 1008 – 4000 cm^3 with a median of 1200 cm^3 and a mean of 2059 cm^3. Egg mass volume was lower in 2007 than in 2002 and 2003, but was not significantly different than in 2004 – 2006. Seven of the egg masses were guarded by six males, leaving one nest unguarded. Guarding males ranged in length from 48 – 79 cm. Differences in guarding male length were not detectable among years. Total lingcod density (guarding and non-guarding males) ranged from 0 – 0.0064 / m^2 with a median of 0.0032 / m^2 and a mean of 0.0030 / m^2. Total lingcod density was lower in 2007 than in 2001 – 2004, but was not significantly different than in 2005 – 2006. Copper rockfish (*S. caurinus*) density ranged from 0 – 0.0286 / m^2 with a median of 0.0111 / m^2 and a mean of 0.0107 / m^2. Quillback rockfish (*S. maliger*) density ranged from 0 – 0.0095 / m^2 with a median of 0 / m^2 and a mean of 0.0026 / m^2. Copper rockfish and quillback rockfish densities were not significantly different among years for 2004 – 2007. Kelp greenling (*Hexagrammos decagrammus*) density ranged from 0 – 0.0095 / m^2 with a median of 0 / m^2 and a mean of 0 / m^2. Kelp greenling density was lower in 2007 than in 2004, but was not significantly different than in 2005 – 2006. Continued nest site affinity was demonstrated by identifying egg masses in 2007 in the same locations as in 2002 – 2004.

RÉSUMÉ

Surry, A.M. and King, J.R. 2007. Lingcod (*Ophiodon elongatus*) egg mass and reef fish density SCUBA survey in the Strait of Georgia, February 13 – 27, 2007. Can. Tech. Rep. Fish. Aquat. Sci: 2743: viii + 19 p.

Nous avons effectué entre le 13 et le 27 février 2007 des relevés en plongée au récif de l'île Snake, dans le détroit de Georgia, en Colombie-Britannique, en vue d'y estimer la densité des masses d'œufs de morue-lingue (*Ophiodon elongatus*) sur le récif, d'y observer les caractéristiques et l'emplacement des masses et d'y estimer la densité de la morue-lingue, des sébastes (*Sebastes* spp.) et d'autres poissons de récif. Le récif de l'île Snake est un site témoin qui avait déjà fait l'objet de relevés en 1990, 1991, 1994 et chaque année entre 2001 et 2006. Des données sur la densité des masses d'œufs ont été recueillies chaque année de relevé; toutefois, les données quantitatives sur le volume des masses ont seulement été recueillies entre 2002 et 2007. Des données sur la longueur des mâles qui gardent les œufs et la densité totale de la morue-lingue ont été recueillies en 1990, puis chaque année entre 2001 et 2007. Des données sur la densité des poissons récifaux ont été recueillies annuellement de 2004 à 2007. L'affinité nids-sites a été examinée en 2002, 2003, 2004 et 2007.

Huit masses d'œufs ont été observées dans une superficie totale de 330 m^2. La densité des masses dans la zone ayant fait l'objet de relevés variait de 0 à 0,0064/m^2 par quadrat. La médiane était de 0/m^2, et la moyenne, de 0,0016/m^2. La densité des masses d'œufs de 2007 était plus faible que celles de 1994, 2002 et 2003, mais elle n'était pas significativement différente de celles observées de 2004 à 2006. Le volume des masses variait de 1 008 à 4 000 cm^3, avec une médiane de 1 200 cm^3 et une moyenne de 2 059 cm^3. Ce volume était plus petit qu'en 2002 et 2003, mais pas significativement différent de ceux observés de 2004 à 2006. Sept masses d'œufs étaient gardées par six mâles; un nid était donc sans gardien. Les mâles qui gardaient les masses d'œufs mesuraient entre 48 et 79 cm de longueur. Nous n'avons pas détecté de variations annuelles dans la longueur des mâles gardiens. La densité totale de la morue-lingue (mâles gardiens et non gardiens) variait entre 0 et 0,0064/m^2, avec une médiane de 0,0032/m^2 et une moyenne de 0,0030/m^2. La densité de 2007 était inférieure à celles observées entre 2001 et 2004, mais elle n'était pas significativement différente de celles de 2005 et 2006. La densité du sébaste cuivré (*S. caurinus*) allait de 0 à 0,0286/m^2, avec une médiane de 0,0111/m^2 et une moyenne de 0,0107/m^2. La densité du sébaste à dos épineux (*S. maliger*) a varié de 0 à 0,0095/m^2, avec une médiane de 0/m^2 et une moyenne de 0,0026/m^2. La densité du sébaste cuivré et du sébaste à dos épineux ne différait pas significativement d'une année à l'autre entre 2004 et 2007. La densité du sourcil de varech (*Hexagrammos decagrammus*) variait de 0 à 0,0095/m^2, avec une médiane de 0/m^2 et une moyenne de 0/m^2. La densité du sourcil de varech était plus faible en 2007 qu'en 2004, mais pas significativement différente des densités observées en 2005 et 2006. L'affinité continue nids-sites a été démontrée par le fait que les masses d'œufs se trouvaient aux mêmes endroits en 2007 qu'entre 2002 et 2004.

INTRODUCTION

Lingcod (*Ophiodon elongatus*) inhabit rocky reefs and spawn in the winter. The eggs are laid in crevices on rocky reefs and are aggressively guarded by male lingcod until the larvae hatch in early spring (Cass *et al.* 1990). Studies have shown that a single female lays each egg mass and that spawning locations are returned to year after year by the same males (Withler *et al.* 2004, King and Withler 2005). A male lingcod can guard more than one egg mass, and unguarded eggs usually succumb to predation (Low and Beamish 1978).

Lingcod have traditionally been a very important species in British Columbia's commercial and recreational fisheries. Lingcod populations in the Strait of Georgia have been severely depressed for several decades but are starting to recover (Richards and Hand 1989, King 2001, Logan *et al.* 2005). Conservation concerns led to the closure of the commercial fishery for lingcod in the Strait of Georgia in 1990, followed by a recreational fishery closure from 2002 – 2005. In 2003, a Stock Assessment Framework for Strait of Georgia lingcod recommended monitoring and assessment programs that would provide measures of the relative abundance and biological parameters for Strait of Georgia lingcod (King et al. 2003). One ongoing source of abundance and biological information has been egg mass density SCUBA surveys, which occurred in 1978 (Low and Beamish 1978), intermittently through the 1990's (Yamanaka and Richards 1995), and annually from 2001 onwards (King and Beaith 2001, King and Winchell 2002, King and Haggarty 2004, Haggarty *et al.* 2005, Haggarty and King 2007, JRK: Unpublished Data).

In 2001, a Stock Assessment document outlined conservation concerns regarding inshore rockfish (*Sebastes spp.*) in the Strait of Georgia and the need for non-intrusive methods of assessing abundance of species at extremely low abundance or in areas with depleted populations (Yamanaka and Lacko 2001). As some species of inshore rockfish in the Strait of Georgia inhabit the same areas and utilize the same habitat as lingcod, visual counts of rockfish may be undertaken during lingcod egg mass density SCUBA surveys. Rockfish density estimates obtained in this manner may be used as auxiliary information to fishery and research surveys for inshore rockfish. From 2004 onwards, visual counts of reef fishes including rockfish have been undertaken during the annual lingcod egg mass density surveys (King and Haggarty 2004, Haggarty *et al.* 2005, Haggarty and King 2007).

Egg mass density surveys have occurred at various locations in the Strait of Georgia including Snake Island Reef, Dodd Narrows and Entrance Island near Nanaimo in Statistical Area 17, and Discovery Passage and Maude Island near Campbell River in Statistical Area 13 (Low and Beamish 1978, Yamanaka and Richards 1995, King and Beaith 2001, King and Winchell 2002, King and Haggarty 2004, Haggarty *et al.* 2005, Haggarty and King 2007, JRK: Unpublished Data). The 2007 egg mass density survey was undertaken at Snake Island Reef, and continues the time series for this index site, which now comprises density estimates from 1990, 1991, 1994 and 2001 – 2007.

METHODS

Dives were conducted by Fisheries and Oceans Canada staff at Snake Island reef near Nanaimo (Figure 1). Dives were conducted from a 6.7 m aluminum tender vessel equipped

with twin 115-hp engines, a depth sounder, GPS, and notebook computer with Nobeltec Visual Navigation Suite v.4.0. Dive positions were randomly selected from areas with a maximum diveable depth of 20 m (approximately 60 ft) in the sections of the reef that have been identified as containing preferred spawning habitat (King and Beaith 2001), utilizing reflectance readings on the depth sounder to target appropriate substrate. Dive positions were distributed over the reef to provide the maximum possible spatial coverage of suitable habitat, and care was taken to avoid overlap of surveyed areas.

The initial survey at Snake Island Reef in 1990 used leadline transects with divers searching for egg masses 7 m on either side of the transect, while subsequent surveys in 1991 and 1994 at Snake Island Reef used circular quadrats with a 10 m radius (Yamanaka and Richards 1995). The method by which transect and quadrat locations on the reef were selected is not described. Surveys in 2001 – 2007 have used similar methodology to that used in 1991 and 1994, but have utilized a more systematic and standardized approach to randomly selecting the quadrat locations (King and Beaith 2001, King and Winchell 2002, King and Haggarty 2004, Haggarty *et al.* 2005, Haggarty and King 2007, JRK: Unpublished Data).

QUADRAT DIVES

For each quadrat dive, an anchor buoy was deployed from the vessel at the selected location, and the position and depth were recorded. Depths were initially recorded in feet for consistency with the divers' depth gauges, and later converted to metres. Depths were not converted to below chart datum since the depth at observation best reflects the spawning habitat used by lingcod during the winter. Divers were equipped with dive lights, a 1-m fabric measuring tape, a 10-m line, and a plastic clipboard with pencils and waterproof paper attached. Two divers descended from the buoy to the anchor weight, and attached the 10-m line to the weight. The divers systematically searched for lingcod egg masses within the circular quadrat formed by sweeping the 10-m line around the weight. The divers used lights where necessary to search within crevices or beneath large flora.

Lingcod Egg Masses

For each egg mass the depth, position, appearance, dimensions, and presence or absence of a guarding male was recorded. Depth was measured in feet using the divers' depth gauges and later converted to metres. Depths were not converted to below chart datum since the depth at observation best reflects the spawning habitat used by lingcod during the winter. The position of the egg mass was either (0) out in the open; (1) under a rock; (2) in a horizontal crevice; or (3) in a vertical crevice. Egg development stages as described by the appearance of the eggs were (0) pink-white = freshly laid; (1) creamy white = new; (2) white = intermediate; (3) grey-white = old; (4) eyed eggs = almost hatched; (5) hatched; or any combination of these, as eggs within an egg mass can be at different stages of development and hatching. The length, width and height of each egg mass was measured in centimetres to estimate its volume. The presence or absence of a guarding male was noted, as well as how many other nests each male was guarding. Guarding males were attributed to an egg mass if they were within 1 – 2 m of the egg mass and exhibited protective or territorial behaviour when the egg mass was approached by a diver. Males that were guarding other nests outside the quadrat were recorded as such, but the other nests were not counted. If possible, the length of each guarding male was measured in centimetres by pulling a measuring tape alongside the fish as it rested on the bottom.

Reef Fishes

In addition to lingcod egg masses and guarding males, divers also counted and recorded non-guarding male lingcod, rockfish adults and juveniles (*Sebastes spp.*), greenlings (*Hexagrammos spp.*), surfperches (Embiotocidae), and any other large (< 20 cm) fishes present within the quadrat. Small, abundant fishes such as sculpins (Cottidae) and gobies (Gobiidae) were not counted

Habitat and substrate characteristics

The habitat within each quadrat was quantified by recording the percentage of the quadrat area (by visual estimate) that corresponded to each of four levels of complexity: simple = smooth, no crevices; low complexity = less than 25% covered by crevices; medium complexity = 25 – 50 % covered by crevices; and high complexity = more than 50% covered by crevices. Similarly, the relief (slope) within the quadrat was quantified by recording the percentage of the quadrat area (by visual estimate) that corresponded to each of four levels of relief: flat (less than a 2 ft difference in depth); low (2 to 7 ft difference in depth); high (over 7 ft difference in depth and/or less than 45 degree slope); wall (greater than 45 degree slope). The substrate within each quadrat was quantified by recording the percentage of the quadrat area (by visual estimate) that corresponded to each of three types of substrate: rock (hardpan, bedrock or boulders); coarse substrate (cobble, gravel, shell); and fine substrate (sand or mud). The coverage of large flora was visually estimated as a percentage of the quadrat area, with common types identified to species.

OBSERVATIONAL DIVES

In 2002 and 2003 a portion of Snake Island reef was surveyed for a genetics and nest site affinity study (Withler et al. 2004, King and Wither 2005). During the study, each nest at the study site was identified with a uniquely numbered plastic tag attached to a brick, so that specific nest sites could be easily identified. King and Withler (2005) observed a high degree of nest site affinity by male lingcod, with 56% of nest site locations used in 2002 re-used in 2003. During the 2007 egg mass survey, observational dives were completed at the genetics site in order to update usage information at the nest sites identified in 2002 and 2003. In 2004, observational dives were also completed at the genetics site (JRK: Unpublished Data). Divers were equipped with a slate on which was drawn a map of locations (including distance between locations) of egg masses used in 2002 – 2003, and they revisited each location, searching for the plastic tags identifying specific nests, and marking the presence or absence of egg masses for the current year. Details about each egg mass and associated male lingcod were recorded in the same manner as for the quadrat dives.

ANALYSIS

Egg mass density (egg masses / m^2) for each quadrat was calculated by dividing the number of egg masses encountered by the area of the circular 10-m radius quadrat. The density of lingcod and other reef fishes was calculated in the same manner.

Egg mass density, egg mass volume, and reef fish densities were compared among years for all years with available data using the Kruskal-Wallace nonparametric analysis of variance (Zar 1999). Multiple comparisons were performed on the ranked data to determine

whether significant differences existed between 2007 and the other years in the time series. The length of guarding lingcod was compared among years for all years with available data using ANOVA (Zar 1999), and multiple comparisons were performed to determine whether significant differences existed among any pair of years in the time series. The relationship between egg mass volume and guarding male length was examined using simple linear regression. All tests were performed at the $\alpha = 0.05$ significance level. The statistics software package S-PLUS version 6.0 for Windows (Insightful Corporation 1988 – 2001) was used to perform all statistical tests.

RESULTS

Sixteen quadrat dives and three observational dives were completed on Snake Island Reef between February 13 and February 27, 2007 (Table 1). Out of a total of nine working days allotted to the survey (February 13 – 14, February 19 – 23, February 26 – 27) weather conditions permitted diving to occur on five days. Suitable weather conditions for entering and exiting the water for diving were generally winds of less than 17 knots, with swells less than 1.0 m and no whitecaps. Quadrats were distributed over the reef at depths ranging from 7.6 m (25 ft) to 13.4 m (44 ft) and generally covered areas of the reef that have been identified as containing suitable nesting habitat, defined as having flat or gradual slope with open, barren areas mixed with rocks, boulders, and crevices, and lacking large concentrations of the brown alga *Agarum sp.* (King and Beaith 2001).

EGG MASS DENSITY

Six quadrats contained lingcod egg masses (Table 1). Eight egg masses were observed within a total surveyed area of 330 m^2. Egg mass density over the sixteen quadrats ranged from 0 – 0.0064/m^2, with a median of 0/m^2 and a mean of 0.0016/m^2.

Egg mass density data was collected at Snake Island Reef in 1990, 1991, 1994, and 2001 – 2007 (Appendix Table 1). Egg mass density in 2007 was the lowest observed for the time series; however the difference in densities among years was for the most part not statistically significant. Egg mass density has been compared among years for some years in previous reports. King and Winchell (2002) found significant differences in density among years for 1991, 1994 and 2001, while Haggarty and King (2007) found no significant differences among years for 2001, 2002 and 2004 – 2006. When egg mass density is compared among all years with available data (1990, 1991, 1994, 2001 – 2007), significant differences do exist (Kruskal Wallace $\chi^2 = 36.0725$, df = 9, p = 0; Figure 2A). Multiple comparisons on the ranked data between 2007 and all other years (i.e. each year compared to 2007) indicated that no significant differences in egg mass density existed between 2007 and 1990 – 1991, and between 2007 and 2004 – 2006, while significant differences did exist between 2007 and 1994, and between 2007 and 2002 – 2003. Examination of the box plots of Figure 2A, indicated that egg mass density was similar among the years 1990 – 1991 and 2004 – 2007 and was lower than in 1994 and 2002 – 2003.

EGG MASS AND GUARDING MALE OBSERVATIONS

Egg Mass Location and Appearance

Of the eight egg masses observed during quadrat dives, one egg mass was located out in the open, five were located under rocks or boulders, and two were located within horizontal or vertical crevices (Table 3). This is consistent with egg mass locations in previous surveys, where the largest proportion of egg masses have been observed under rocks or boulders (Yamanaka and Richards 1995; King and Beaith 2001, King and Winchell 2002, King and Haggarty 2004, Haggarty *et al.* 2005, Haggarty and King 2007, JRK: Unpublished Data). Egg mass appearance ranged from stage 1 (creamy white = fresh) to stage 4 (eyed), with one egg mass at stage 1 (creamy-white = new), two egg masses a combination of stages 1 and 2 (creamy-white/white = new/intermediate), one egg mass a combination of stages 2 and 3 (white/grey-white = intermediate/old), and four egg masses at stage 4 (eyed) (Table 3). This is consistent with egg mass development in previous surveys at Snake Island, where all developmental stages have been present, but the highest proportion have been in the later stages of development (Yamanaka and Richards 1995; King and Beaith 2001, King and Winchell 2002, King and Haggarty 2004, Haggarty *et al.* 2005, Haggarty and King 2007, JRK: Unpublished Data).

Egg Mass Volume

Egg mass volume in the quadrats ranged from 1008 – 4000 cm^3 with a median of 1200 cm^3 and a mean of 2059 cm^3 (Table 3). Egg mass volume was estimated in 1990 and 2001, and measured quantitatively in 2002 – 2007; only the quantitative measurements for 2002 – 2007 are considered in this report (Appendix Table 1). Egg mass volume has not previously been compared among years. Significant differences in egg mass volume exist among years for the 2002 – 2007 time series (Kruskal Wallace $\chi^2 = 19.964$, df = 5, $p = 0.0013$; Figure 2B). Egg mass volume in 2007 was the lowest observed for the time series; however examination of the box plots of Figure 2B indicated that egg mass volumes were similar among years for 2004 – 2007 and were lower than in 2002 – 2003. This is reflected by the results of multiple comparison testing on the ranked data between 2007 and all other years (i.e. each year compared to 2007) which indicated that no significant differences in egg mass volume existed between 2007 and 2004 – 2006, while significant differences did exist between 2007 and 2002 – 2003.

Guarding Males

Seven of the eight observed egg masses were guarded by six males, with one male guarding two nests (Table 3). These results are consistent with previous surveys, where typically over 70 % of the observed nests are guarded, and over 60% of the guarding males are guarding only one nest (Yamanaka and Richards 1995, King and Beaith 2001, King and Winchell 2002, King and Haggarty 2004, Haggarty *et al.* 2005, Haggarty and King 2007, JRK: Unpublished Data). The unguarded nest was not observed to be predated upon, but observations in previous surveys indicate that unguarded nests quickly succumb to predation (Low and Beamish 1978, King and Beaith 2001).

Five of the six guarding males observed in the quadrats were measured, and ranged in length from 48 – 79 cm (Table 3). The length of guarding males was also measured in 1990 and in 2001 – 2006 (Appendix Table 1). Overall, guarding male length ranged from 40 – 85 cm (Figure 3). A previous report compared guarding male length among years for 1990,

2001, and 2002 and found that mean length in 2002 was significantly greater than in 2001, but was not significantly different than in 1990 (King and Winchell 2002). With the addition of 2003 – 2007 data to the time series, ANOVA still indicates significant differences in mean length among years ($F = 2.69$, $p = 0.011$); however, multiple comparison testing was not able to detect any significant differences in mean length among any pair of years.

Egg Mass Volume as a Function of Guarding Male Length

Egg mass volume was examined as a function of guarding male length for each year from 2002 – 2007 (Figure 3). No relationship was found for any year ($p > 0.060$) or for all years combined ($p = 0.432$). In 2004 egg mass volume and guarding male length was examined graphically and no relationship was found (King and Haggarty 2004).

REEF FISH DENSITY

Lingcod

In addition to the six guarding male lingcod observed in the quadrats, nine non-guarding male lingcod were observed (Table 4). Total lingcod density in each quadrat ranged from 0 – 0.0064 / m^2 with a median of 0.0032 / m^2 and a mean of 0.0030 / m^2. Guarding and non-guarding lingcod were also counted in 2001 – 2006 (Appendix Table 1 and Figure 4).

A previous report compared lingcod densities among years for 2001 – 2002 and 2004 – 2006 (Haggarty and King 2007) and found significant differences. With the addition of 2003 and 2007 data, significant differences also exist (Kruskal Wallace $\chi^2 = 42.7146$, $df = 6$, $p = 0$; Figure 4). Median lingcod density in 2007 was identical to median lingcod density in 2005 and 2006, and lower than that observed in 2001 – 2004, where each year the median density was 0.009549 / m^2 (Figure 4). Multiple comparisons on the ranked data between 2007 and all other years (i.e. each year compared to 2007) reflected this, and indicated that no significant differences in lingcod density existed between 2007 and 2005 – 2006, while significant differences did exist between 2007 and 2001 – 2004.

Other Reef Fishes

Copper rockfish (*Sebastes caurinus*), quillback rockfish (*S. maliger*) and kelp greenling (*Hexagrammos decagrammus*) were the most consistently encountered reef fishes other than lingcod (Table 4). In addition, divers encountered one tiger rockfish (*S. nigrocinctus*), one striped seaperch (*Embiotoca lateralis*) and one wolf-eel (*Anarrhichthys ocellatus*). Reef fish were encountered in all quadrats except quadrat 1. Copper rockfish density ranged from 0 – 0.0286 / m^2 with a median of 0.0111 / m^2 and a mean of 0.0107 / m^2. Quillback rockfish density ranged from 0 – 0.0095 / m^2 with a median of 0 / m^2 and a mean of 0.0026 / m^2. Kelp greenling density ranged from 0 – 0.0095 / m^2 with a median of 0 / m^2 and a mean of 0 / m^2.

Quadrat counts of reef fishes other than lingcod have been completed at Snake Island Reef each year from 2004 – 2007 (Appendix Table 1 and Figure 4). When densities were compared among years for copper rockfish, quillback rockfish and kelp greenling, only kelp greenling densities showed significant differences among years (Kruskal Wallace $\chi^2 = 9.7044$, $df = 3$, $p = 0.021$; Figure 4). Multiple comparisons on the ranked data between 2007 and all other years (i.e. each year compared to 2007) showed that kelp greenling density in 2007 was

significantly different than in 2004 but there were no significant differences between 2007 and 2005 or 2006. Examination of the kelp greenling box plot in Figure 4 shows that kelp greenling density was similar among the years 2005 – 2007, and lower than in 2004.

SITE AFFINITY

An observational dive at the location previously surveyed for genetic and site affinity studies in 2002 – 2003 (Withler et al. 2004, King and Wither 2005) yielded three egg masses, each guarded by one male (Table 5). The males ranged in length from 50 – 56 cm. Egg mass volume was 1500 – 4860 cm^3. The 2004 dive survey also revisited the genetic site and observed seven egg masses (JRK: Unpublished Data). The locations of egg masses observed in 2004 and in 2007 at the genetics site correspond to locations of egg masses observed in 2002 and 2003 (Withler et al. 2004, King and Wither 2005), indicating that some of the same nest sites continue to be utilized over at least a six year period.

DISCUSSION

This is the tenth year that lingcod egg mass density has been estimated at the Snake Island Reef index site, and the seventh consecutive year since 2001. Based on the quadrat densities observed in each survey year, there has not been any dramatic or sustained change in egg mass densities since 1990, although some exceptional years do stand out. Egg mass density, egg mass volume, and total lingcod density for 2007 were observed to be among the lowest of the time series, although for the most part the differences between 2007 and other years are not statistically significant. Some specific nest sites observed in 2002 and 2003 continue to be used for egg masses in 2007, further illustrating the strong site affinity described by King and Withler (2005).

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Table 1. Position and depth of anchor buoy, visibility, number of guarded and un-guarded lingcod egg masses, and egg mass density (egg masses / m^2) , for quadrat dives and observational dives at Snake Island Reef, February 13 – 27, 2007.

Quadrat	Date	Latitude	Longitude	Depth (m)	Visibility (m)	No. Egg Masses		
						Guarded	Not Guarded	Density
1	Feb 13	49° 12' 44.1"	123° 53' 6.0"	8.8	12	0	0	0
2	Feb 13	49° 12' 45.2"	123° 53' 2.5"	8.8	12	1	0	0.003183
3	Feb 13	49° 12' 43.3"	123° 53' 1.8"	12.5	10	1	1	0.006366
4	Feb 13	49° 12' 42.5"	123° 53' 6.0"	7.6	10	0	0	0
5	Feb 13	49° 12' 40.2"	123° 53' 8.3"	9.8	13	1	0	0.003183
6	Feb 20	49° 12' 39.0"	123° 53' 6.0"	8.8	8	1	0	0.003183
7	Feb 20	49° 12' 40.9"	123° 53' 7.0"	9.8	8	0	0	0
8	Feb 20	49° 12' 39.3"	123° 53' 8.1"	12.8	8	0	0	0
9	Feb 23	49° 12' 37.4"	123° 53' 7.6"	13.4	9	0	0	0
10	Feb 23	49° 12' 38.1"	123° 53' 2.8"	13.4	8	0	0	0
11	Feb 23	49° 12' 40.6"	123° 53' 0.7"	12.8	9	0	0	0
12	Feb 23	49° 12' 41.2"	123° 53' 7.0"	12.8	8	0	0	0
13	Feb 23	49° 12' 40.2"	123° 53' 6.9"	9.8	10	0	0	0
14	Feb 23	49° 12' 41.3"	123° 53' 2.7"	8.2	8	0	0	0
15	Feb 26	49° 12' 43.9"	123° 53' 4.8"	9.1	10	2	0	0.006366
16	Feb 27	49° 12' 41.9"	123° 53' 2.8"	10.4	8	1	0	0.003183
n/a	Feb 27	49° 12' 43.9"	123° 53' 4.7"	9.8	--	--	--	--
n/a	Feb 27	49° 12' 43.6"	123° 53' 4.9"	8.8	--	--	--	--
Genetics	Feb 27	49° 12' 43.6"	123° 53' 4.7"	9.1	--	3	--	--

Table 2. Complexity of habitat, relief (slope), substrate type, and coverage by *Agarum sp.* for lingcod egg mass quadrat dives at Snake Island Reef, February 13 – 27, 2007. Quadrats indicated with bold type contained egg masses.

Quadrat	Date	Complexity [a] (% of quadrat)				Relief [b] (% of quadrat)				Substrate [c] (% of quadrat)			Agarum (% of quadrat)
		Simple	Low	Medium	High	Flat	Low	High	Wall	Rock	Coarse	Fine	
1	Feb 13	80	20	0	0	80	20	0	0	100	0	0	20
2	**Feb 13**	**70**	**30**	**0**	**0**	**0**	**100**	**0**	**0**	**90**	**10**	**0**	**0**
3	**Feb 13**	**0**	**50**	**50**	**0**	**50**	**50**	**0**	**0**	**50**	**50**	**0**	**30**
4	Feb 13	30	70	0	0	30	70	0	0	50	50	0	0
5	**Feb 13**	**60**	**30**	**10**	**0**	**50**	**50**	**0**	**0**	**80**	**20**	**0**	**0**
6	**Feb 20**	**50**	**10**	**40**	**0**	**50**	**50**	**0**	**0**	**100**	**0**	**0**	**0**
7	Feb 20	50	20	30	0	60	40	0	0	80	20	0	0
8	Feb 20	0	30	70	0	0	60	40	0	90	10	0	0
9	Feb 23	10	60	30	0	50	25	0	25	90	10	0	0
10	Feb 23	0	10	0	90	50	50	0	0	90	10	0	80
11	Feb 23	0	0	0	100	0	100	0	0	95	5	0	90
12	Feb 23	60	20	20	0	0	40	40	20	90	10	0	0
13	Feb 23	50	25	25	0	50	50	0	0	80	20	0	0
14	Feb 23	40	0	60	0	0	50	50	0	90	10	0	40
15	**Feb 26**	**50**	**25**	**25**	**0**	**100**	**0**	**0**	**0**	**60**	**40**	**0**	**0**
16	**Feb 27**	**10**	**0**	**90**	**0**	**50**	**50**	**0**	**0**	**90**	**10**	**0**	**90**

[a] Complexity: Simple = smooth, no crevices; Low = less than 25% covered by crevices; Medium = 25 – 50 % covered by crevices; High = more than 50% covered by crevices.

[b] Relief: Flat (less than a 2 ft difference in depth); Low (2 to 7 ft difference in depth); High (over 7 ft difference in depth and/or < 45°slope); Wall (> 45 ° slope).

[c] Substrate: Rock (hardpan, bedrock or boulders); Coarse (cobble, gravel, shell); Fine (sand or mud).

Table 3. Characteristics of each egg mass and guarding male observed during quadrat dives at Snake Island Reef, February 13 – 27, 2007. Egg masses are numbered consecutively in the order in which they were discovered. "N/A" indicates "not available" and refers to egg masses that were located too far under a rock to measure, or males that swam away before they could be measured.

Date	Egg Mass	Quadrat	Depth (m)	Egg Mass Location [a]	Appearance [b]	Volume (cm^3)	Male Present [c]	Male length (cm)
Feb 13	1	2	10.4	2	1/2	1200	M1	48
Feb 13	2	3	13.7	1	4	N/A	M1	N/A
Feb 13	3	3	13.7	1	4	1014	M0	--
Feb 13	4	5	9.4	0	2/3	2990	M1	79
Feb 20	5	6	9.8	1	4	1008	M1	62
Feb 26	6	15	8.8	1	4	3000	M2	51
Feb 26	7	15	8.8	1	2	4000	M2	51
Feb 27	8	16	11.9	3	2	1200	M1	N/A

[a] Egg Mass Locations: (0) out in the open; (1) under a rock; (2) in a horizontal crevice; or (3) in a vertical crevice.

[b] Appearance: (1) creamy = new; (2) white = intermediate; (3) grey-white = old; (4) eyed eggs = almost hatched; (5) hatched.

[c] Type of Male: (M0) = no guarding male present; (M1) = male guarding one egg mass; (M2) = male guarding two egg masses

Table 4. Reef fish observations from quadrat dives at Snake Island Reef, February 13 – 27, 2007. Total counts and densities (fish / m^2) in each quadrat are provided for lingcod (*Ophiodon elongatus*), copper rockfish (*Sebastes caurinus*), quillback rockfish (*S. maliger*) and kelp greenling (*Hexagrammos decagrammus*). For lingcod, the number of guarding males included in the total is indicated in brackets. For copper and quillback rockfish, the number of juveniles included in the total is indicated in brackets. For kelp greenling, the number of males (m) and/or females (f) included in the total is indicated in brackets. Total counts in each quadrat are provided for tiger rockfish *(S. nigrocinctus)*, striped seaperch (*Embiotoca lateralis*) and wolf-eel (*Anarrhichthys ocellatus*).

	Lingcod		Copper rockfish		Quillback rockfish		Kelp greenling		Tiger	Striped	Wolf-
Quadrat	Count	Density	Count	Density	Count	Density	Count	Density	rockfish	seaperch	eel
1	0	0	0	0	0	0	0	0	0	0	0
2	1 (1)	0.003183	1	0.003183	1	0.003183	0	0	0	0	0
3	1 (1)	0.003183	4	0.012732	1	0.003183	1 (1m)	0.003183	0	0	0
4	1	0.003183	0	0	0	0	0	0	0	0	1
5	2 (1)	0.006366	4	0.012732	0	0	0	0	0	0	0
6	2 (1)	0.006366	9	0.028648	0	0	1 (1m)	0.003183	0	0	0
7	0	0	0	0	1 (1)	0.003183	0	0	0	0	0
8	1	0.003183	6 (1)	0.019099	0	0	1 (1m)	0.003183	0	0	0
9	0	0	1	0.003183	0	0	0	0	0	0	0
10	0	0	5 (2)	0.015916	3 (1)	0.009549	1 (1f)	0.003183	1	1	0
11	2	0.006366	9 (1)	0.028648	3	0.009549	2 (1f / 1m)	0.006366	0	0	0
12	2	0.006366	0	0	2 (1)	0.006366	0	0	0	0	0
13	0	0	2	0.006366	0	0	1 (1m)	0.003183	0	0	0
14	0	0	3	0.009549	0	0	3 (3f)	0.009549	0	0	0
15	1 (1)	0.003183	5 (2)	0.015916	0	0	1 (1f)	0.003183	0	0	0
16	2 (1)	0.006366	5	0.015916	2	0.006366	1 (1f)	0.003183	0	0	0

Table 5. Characteristics of egg masses and guarding males observed during observational dives at the Genetics site at Snake Island Reef, February 27, 2007, and February 20, 2004 (JRK: Unpublished Data). Egg masses are numbered according to the numbered locations established in 2002 and 2003 (King and Wither 2005). "N/A" indicates "not available" and refers to males that swam away before they could be measured. "--" indicates no measurements were recorded.

Year	Egg Mass	Depth (m)	Egg Mass Location [a]	Appearance [b]	Volume (cm^3)	Male Present [c]	Male length (cm)
2007	6	8.8	1	3/4	1500	M1	50
2007	12	8.8	1	4	4860	M1	56
2007	16	7.6	1	2/3	2000	M1	51
2004	2	--	--	--	--	M0	--
2004	3	--	--	--	--	--	--
2004	4	6.4	1	3	1620	M1	N/A
2004	6	6.4	1	3	3640	M1	65
2004	12	--	--	--	--	M1	--
2004	15	--	--	--	--	M1	--
2004	18	6.4	2	3/4	2970	M1	71

[a] Egg Mass Locations: (0) out in the open; (1) under a rock; (2) in a horizontal crevice; or (3) in a vertical crevice.

[b] Appearance: (1) creamy = new; (2) white = intermediate; (3) grey-white = old; (4) eyed eggs = almost hatched; (5) hatched.

[c] Type of Male: (M0) = no guarding male present; (M1) = male guarding one egg mass; (M2) = male guarding two egg masses

Figure 1. Location and bathymetry of Snake Island Reef in the Strait of Georgia near Nanaimo, British Columbia, study site for lingcod egg mass and reef fish density surveys in 1990, 1991, 1994 and 2001 – 2007.

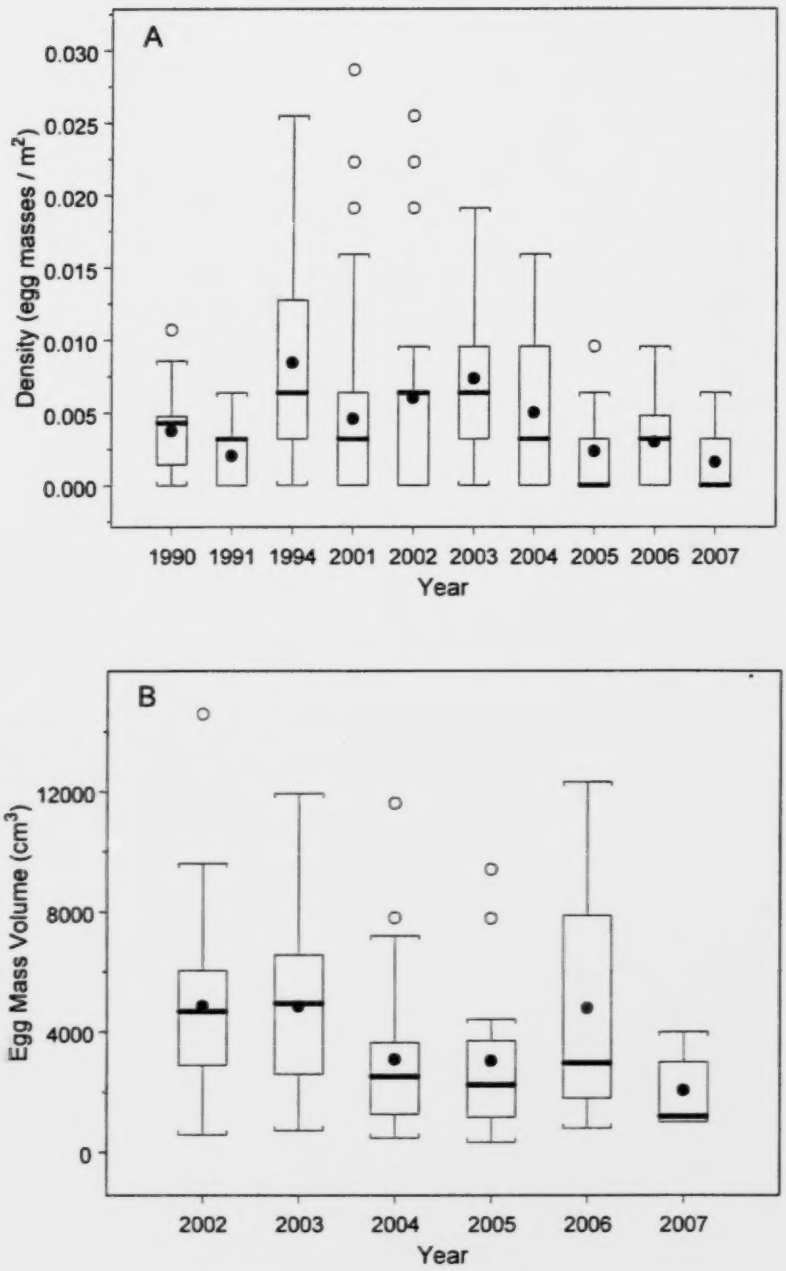

Figure 2. A) Box plots of lingcod egg mass densities at Snake Island Reef in 1990, 1991, 1994, and 2001 – 2007; and B) box plots of lingcod egg mass volumes at Snake Island Reef in 2002 – 2007. The heavy horizontal line inside each box represents the median, while box edges depict the 1st and 3rd quartiles. The range of the data are represented by the whiskers. The mean density is represented by •, while outliers are represented by ○.

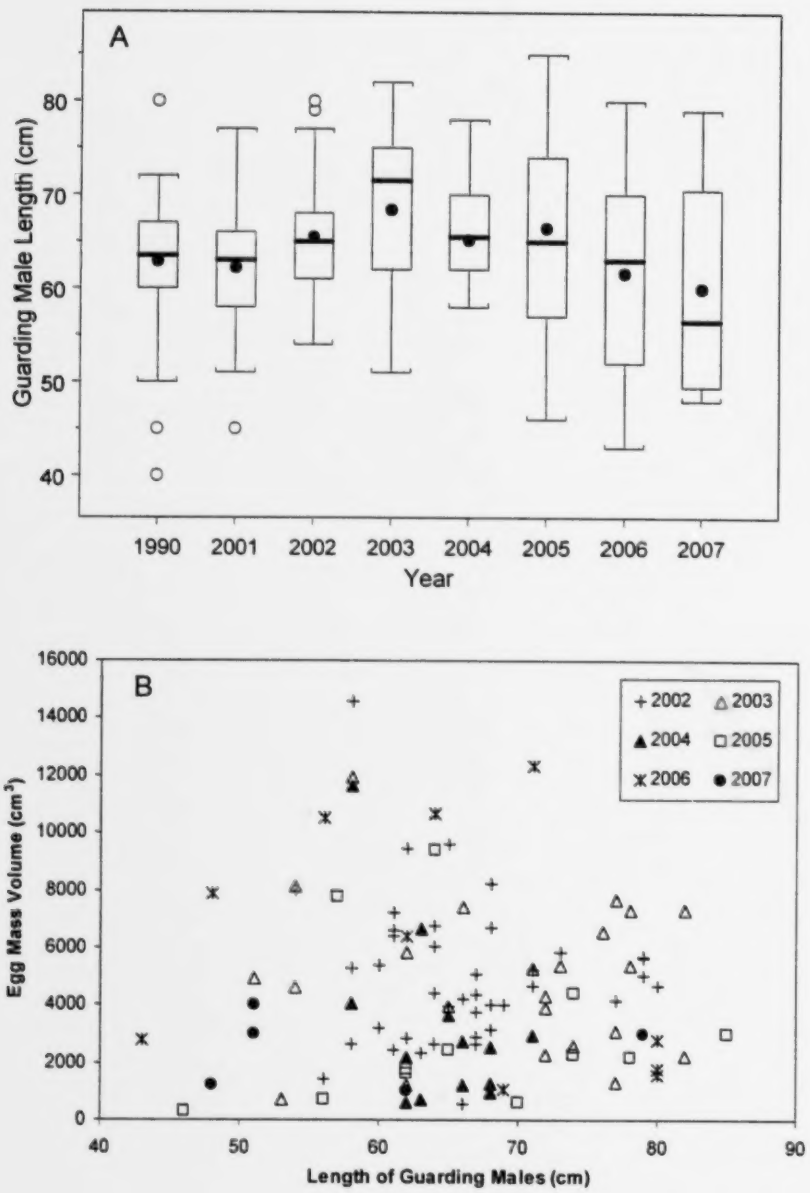

Figure 3. A) Box plots of guarding lingcod densities at Snake Island Reef in 1990 and 2001 – 2007; and B) egg mass volume as a function of guarding male length for 2002 – 2007. For box plots, the heavy horizontal line inside each box represents the median, while box edges depict the 1st and 3rd quartiles; the range of the data are represented by the whiskers; the mean density is represented by •, while outliers are represented by ○.

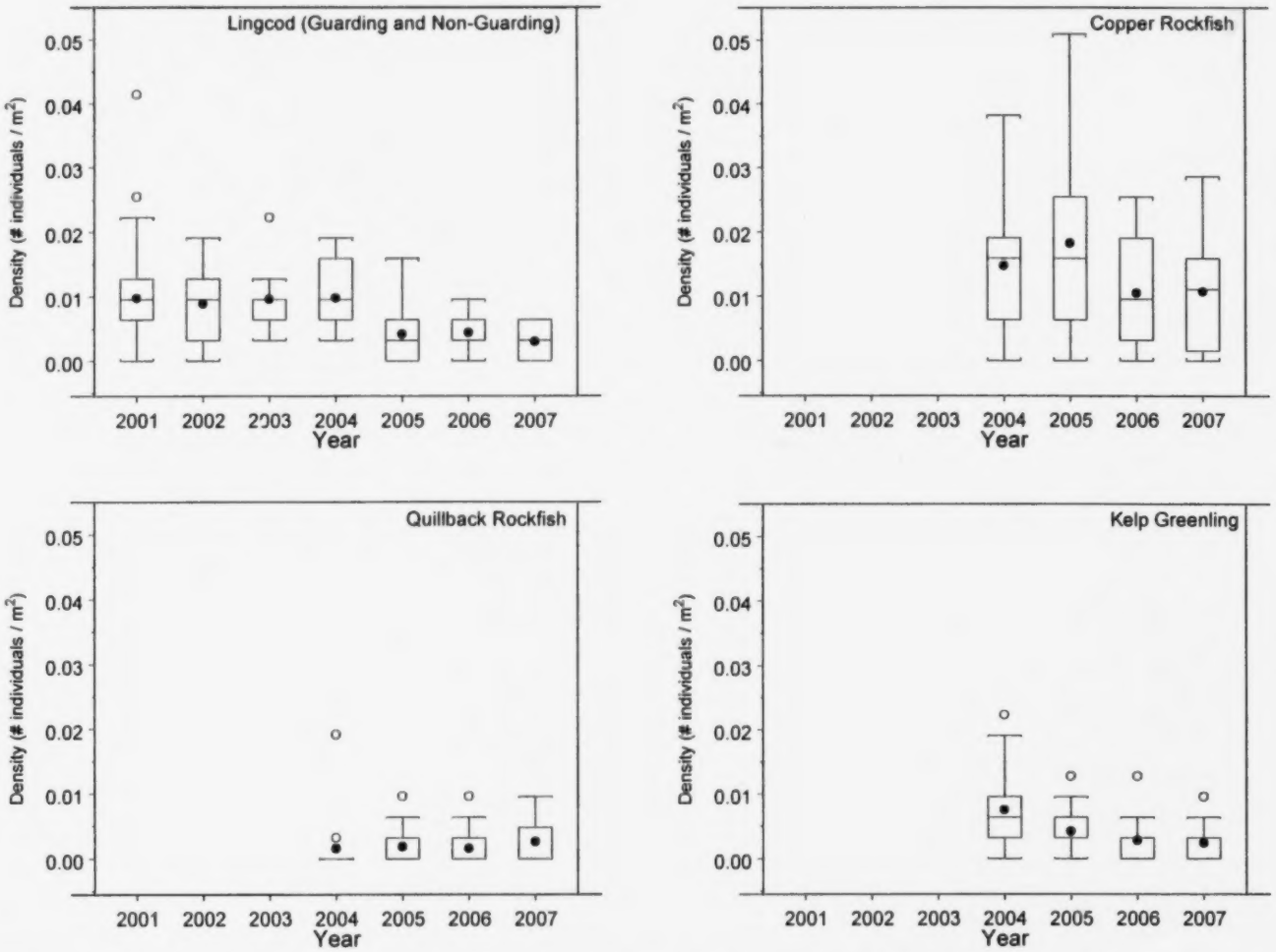

Figure 4. Box plots of reef fish densities at Snake Island Reef for lingcod in 2001 – 2007 and copper rockfish, quillback rockfish, and kelp greenling in 2004 – 2007 . The heavy horizontal line inside each box represents the median, while box edges depict the 1st and 3rd quartiles. The range of the data are represented by the whiskers. The mean density is represented by •, while outliers are represented by ○.

Appendix Table 1. Summary of lingcod egg mass density and volume, lengths of guarding males, and density of reef fishes at Snake Island Reef in 1990, 1991 and 1994 (Yamanaka and Richards 1995, K.L. Yamanaka, Unpublished Data, Pacific Biological Station, Nanaimo, BC V9T 6N7), 2001 (King and Beaith 2001), 2002 (King and Winchell 2002), 2003 (JRK: Unpublished Data), 2004 (King and Haggarty 2004), 2005 (Haggarty *et al.* 2005), 2006 (Haggarty and King 2007), and 2007.

Year	Time Period	Number of Egg Masses	Number of Quadrats / Transects	Egg Masses				Guarding Lingcod [b]	
				Density (egg masses / m^2)		Volume (cm^3) [a]		Mean Length (cm)	No. Measured
				Median	Mean	Median	Mean		
1990	Feb 16 – Mar 16	104	37	0.004286	0.003745	--	--	62.87	54
1991	Mar 18 – Mar 21	14	22	0.003183	0.002026	--	--	--	0
1994	Feb 10 – Mar 15	78	29	0.006366	0.008452	--	--	--	0
2001	Jan 23 – Apr 6	107	74	0.003183	0.004856	--	--	62.22	73
2002	Feb 1 – Mar 13	51	27	0.006366	0.006013	4680.0	4862.55	65.49	39
2003	Feb 12 – Feb 21	30	13	0.006366	0.007346	4950.0	4852.41	68.40	20
2004	Feb 17 – Mar 3	22	14	0.003183	0.005002	2145.0	3049.67	65.59	17
2005	Mar 3 – Mar 8	14	19	0.000000	0.002345	2241.5	3044.25	66.45	11
2006	Mar 3 – Mar 7	15	16	0.003183	0.002984	2970.0	4796.60	61.63	8
2007	Feb 13 – Feb 27	8	16	0.000000	0.001592	1200.0	2058.86	60.00	4

Year	Time Period	Reef Fish Density (number of fish / m^2)							
		Lingcod [c]		Copper rockfish [d]		Quillback rockfish [d]		Kelp greenling [d]	
		Median	Mean	Median	Mean	Median	Mean	Median	Mean
1990	Feb 16 – Mar 16	--	--	--	--	--	--	--	--
1991	Mar 18 – Mar 21	--	--	--	--	--	--	--	--
1994	Feb 10 – Mar 15	--	--	--	--	--	--	--	--
2001	Jan 23 – Apr 6	0.009549	0.009721	--	--	--	--	--	--
2002	Feb 1 – Mar 13	0.009549	0.008842	--	--	--	--	--	--
2003	Feb 12 – Feb 21	0.009549	0.009549	--	--	--	--	--	--
2004	Feb 17 – Mar 3	0.009549	0.009777	0.015916	0.014779	0.000000	0.001592	0.006366	0.007503
2005	Mar 3 – Mar 8	0.003183	0.004188	0.015916	0.018261	0.000000	0.001843	0.003183	0.004188
2006	Mar 3 – Mar 7	0.003183	0.004377	0.009549	0.010544	0.000000	0.001592	0.003183	0.002785
2007	Feb 13 – Feb 27	0.003183	0.002984	0.011141	0.010743	0.000000	0.002586	0.003183	0.002387

Notes:
a) Egg mass volumes were not measured systematically prior to 2002.
b) Guarding males were not measured in 1991 and 1994.
c) Lingcod density includes guarding and non-guarding males; non-guarding males were not counted prior to 2001.
d) Other reef fishes were not counted prior to 2004.